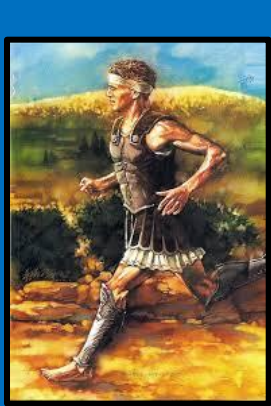# An Analysis of Physiological and Running Metrics in 3K Cross Country Running in comparison to Track and Treadmill

Introduction:

The use of wearable technologies (wearables) like our VivoActive 3 Garmin, fitness trackers and footpods has increased in recent years [1]. Wearables have been cited as an advancement in distance running since they provide more precise data than classic self-assessment can as athletes and their coaches take advantage of technological advancements to track data over time to pinpoint areas for improvement [2].

Aim:

Our aim is to statistically analyse and compare Physiological metrics (Heart rate) and Running metrics (Cadence, Running Power and Stride length) data gathered using "wearables" across three different running surfaces e.g Cross Country (XC) versus Track versus Treadmill. Our overall hypothesis is that cross country running should be better preparation for middle distance to long distance running events (anecdotal evidence) due to training at different elevations (hills) and on a natural surface that the human body has evolved to run on over time, rather than on a man made flat surface. XC running should be better preparation for any long distance runner because it adds variation to cadence, stride length and power – this is due to the effect of hills. This should (we hypothesise) translate into higher average heart rates, higher average running power, higher average cadence and stride length for XC running in comparison to the other two surface types.

Experimental Design (Factors considered) for Reliability of Data:

(1) Calibration of Treadmill.
(2) Use of Stryd device to capture data.
(3) Use of VivoActive 3 Garmin device to capture data.

Experimental Design (Factors considered) for Validity of Data:

(1) Cross section of runners of different ability and experience levels (i.e. Elite runners, Casual Runners, Non-Runners).
(2) Sample size – Number of test subjects was 30.
(3) Test `environment – A `lack` of `pure` repeatability is inherent in human activities (i.e. running), Consistent performance can reduce the effect of this error e.g.
    (a) Same Treadmill, "Technogym" model (Indoor with calibrated Treadmill).
    (b) Track (Same track location and surface used e.g. Tarten surface).
    (c) Cross country route (Same route used on the same International Course during a short time window, mid Oct. to mid Nov., to minimise weather effects).
    (d) Each participant used the same running shoes on each surface to eliminate the effect of differences in grip that different shoes would yield.
    (e) Runners carried out the Same Pre Warm Up and Post Cool Down run routines involving the same Stretching routine.

This was all done to minimise any changes in the test environment , and that any changes (XC vs Track vs Treadmill) affected runners equally.

Experimental Design (Factors considered) for Reduction of Bias:

(1) Researcher Bias – Experimental data and statistical tests results were independently coded by both members of the group and an engineer to facilitate blind analysis.
(2) Omission/Inclusion Bias (a) Test subjects (runners) were drawn from same province with three different coaches.
    (b) Included males and females, ages 14 To 50 Years old.
(3) Measurement Bias - The Treadmill was calibrated to 1% accuracy, The Stryd (1%) and Garmin (1.5%).
(4) Benchmarking – The experimental data was compared to peer reviewed studies.

Experimental Set-up:

(1) A number of tests were ran measuring the following running metrics.
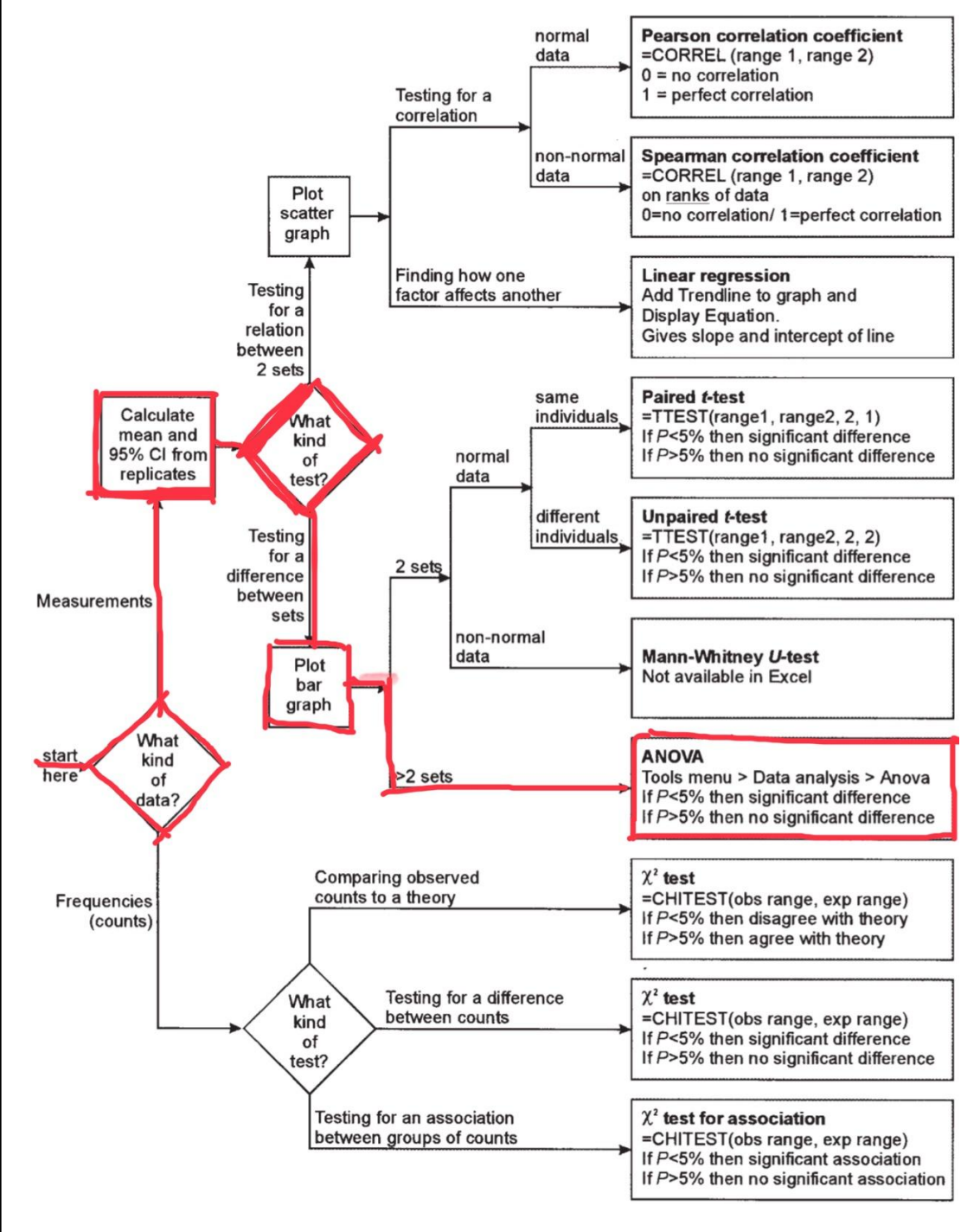Heart Rate in Beats per minute,
Power in Watts,
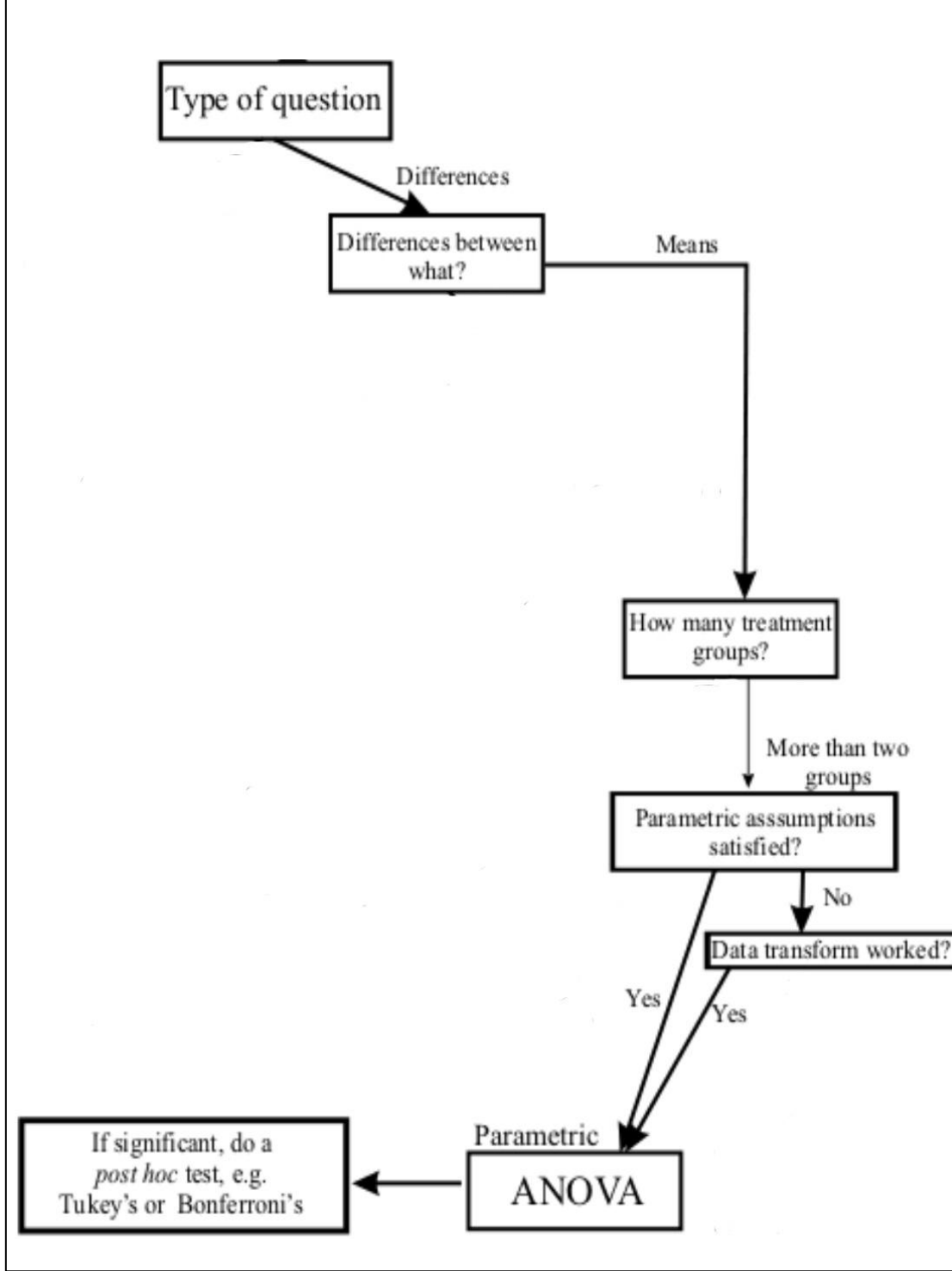Cadence in Strides per minute,
Stride length in Metres.

Statistical Assessment:

The following Statistical Flow Charts were used to Statistically compare the different running metrics for the three different types of running (groups) to find out if there was any significant statistical differences between them.
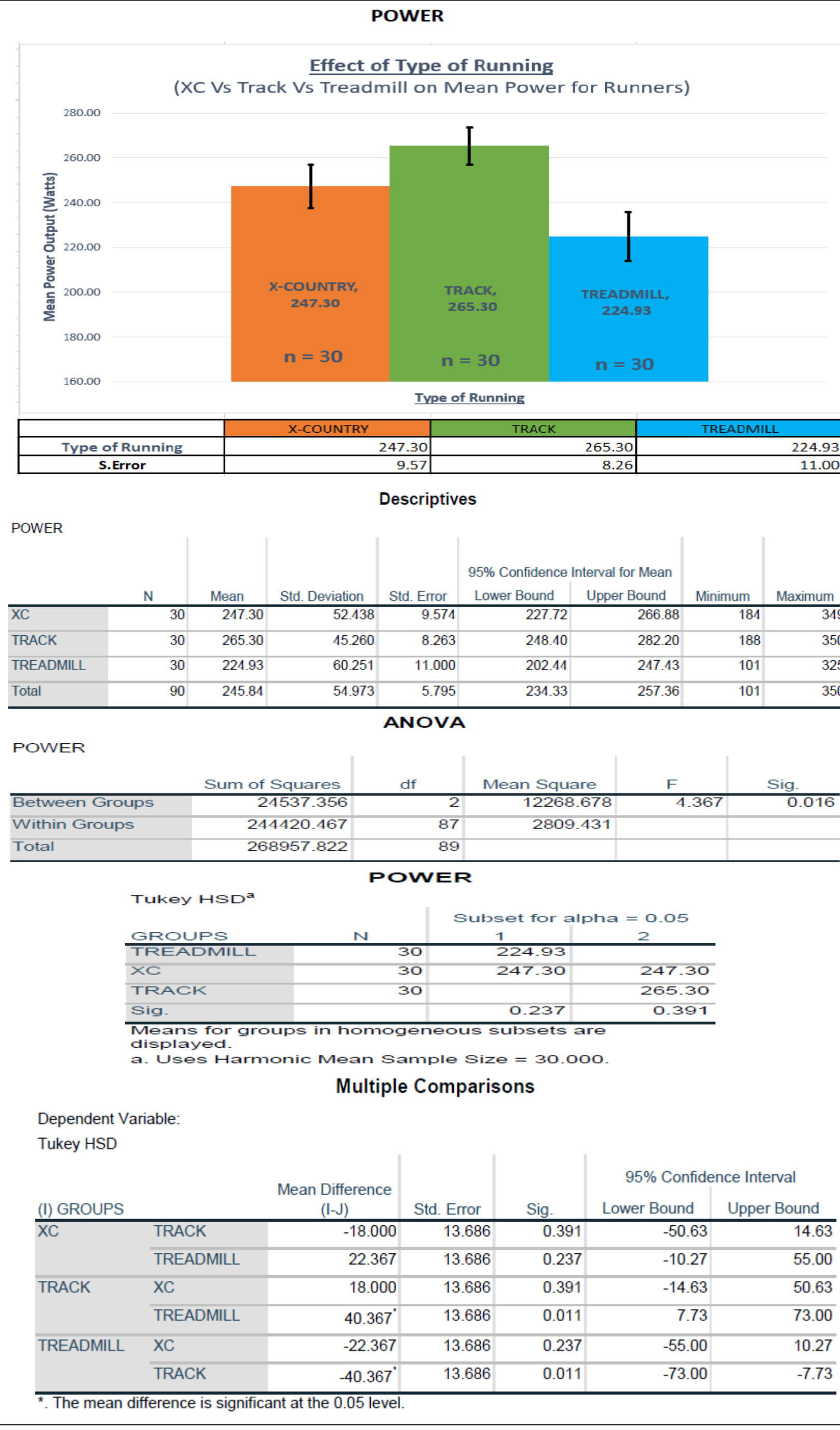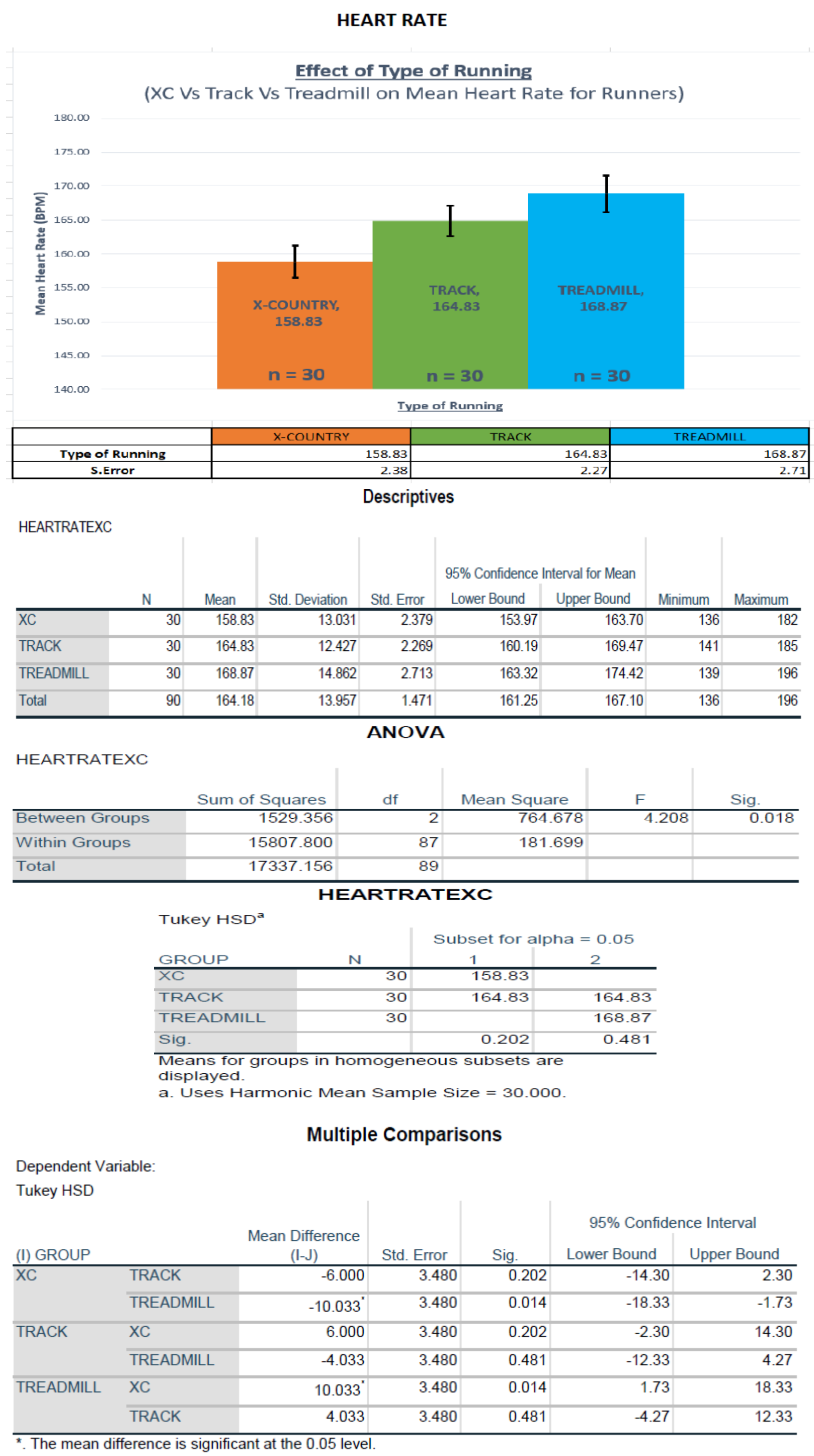
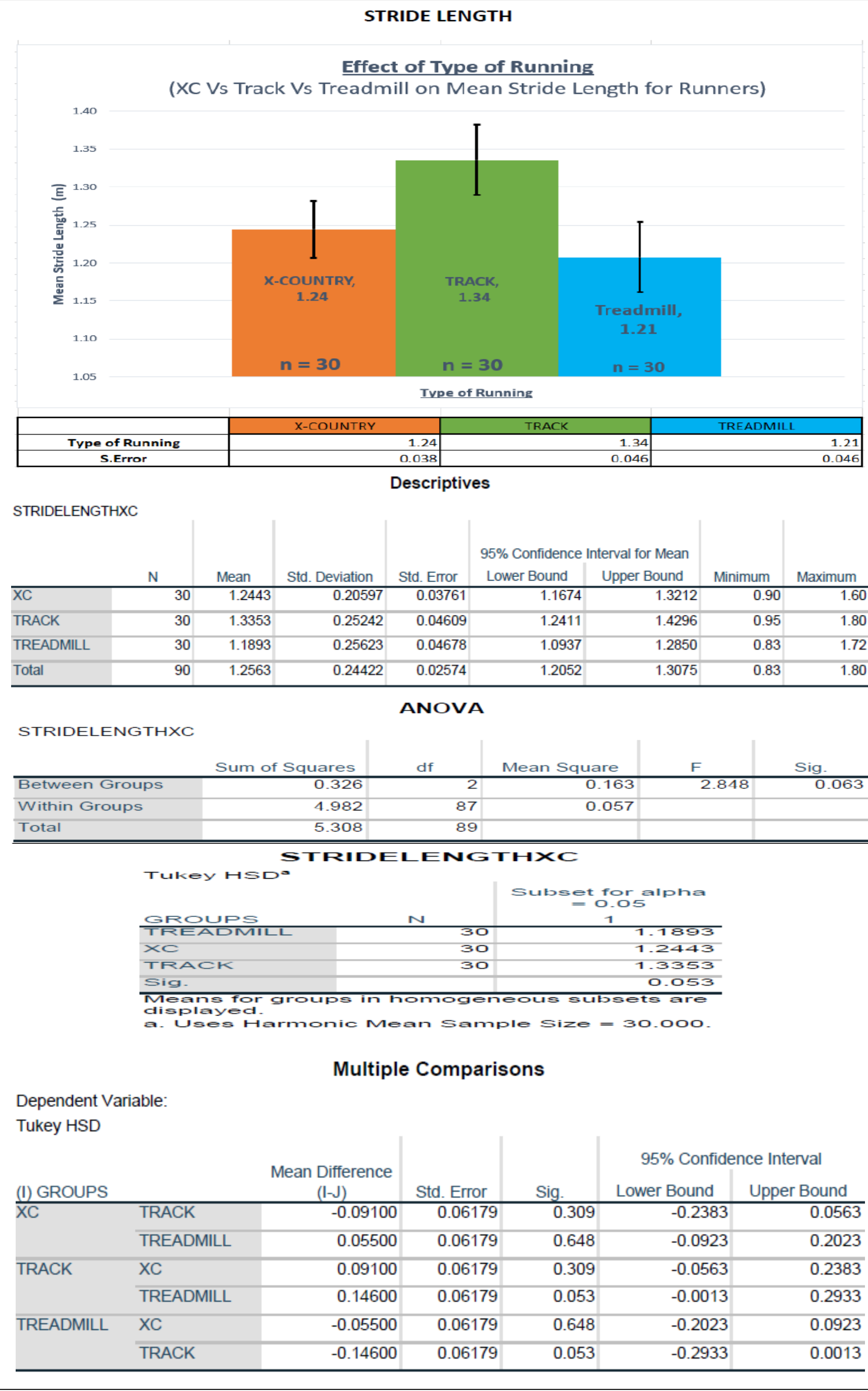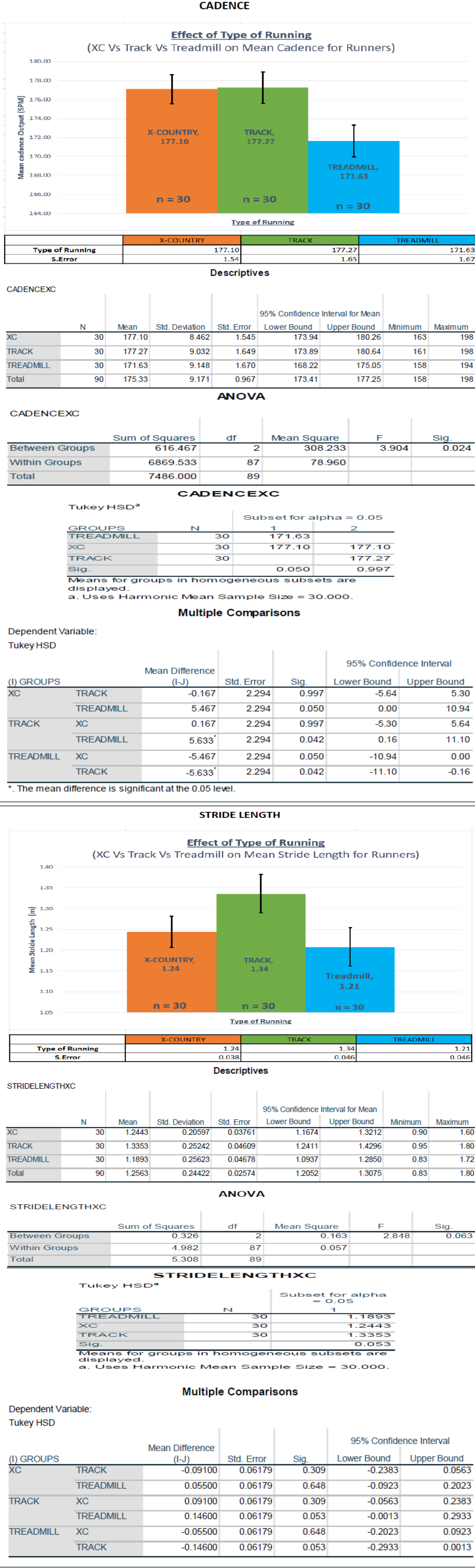Adapted From: Neil Millar. School Science Review, Dec 2001, 83, (303).

Adapted From: www.twitter.com

Results:

HEART RATE

Effect of Type of Running
(XC Vs Track Vs Treadmill on Mean Heart Rate for Runners)

Type of Running	X-COUNTRY	TRACK	TREADMILL
Type of Running	158.83	164.83	168.87
S.Error	2.38	2.27	2.71

Descriptives
HEARTRATEXC

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	Upper Bound	Minimum	Maximum
XC	30	158.83	13.031	2.379	153.97	163.70	136	182
TRACK	30	164.83	12.427	2.269	160.19	169.47	141	185
TREADMILL	30	168.87	14.862	2.713	163.32	174.42	139	196
Total	90	164.18	13.957	1.471	161.25	167.10	136	196

ANOVA
HEARTRATEXC

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1529.356	2	764.678	4.208	0.018
Within Groups	15807.800	87	181.699		
Total	17337.156	89			

Tukey HSD[a]
HEARTRATEXC

GROUP	N	Subset for alpha = 0.05 1	2
XC	30	158.83	
TRACK	30	164.83	164.83
TREADMILL	30		168.87
Sig.		0.202	0.481

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 30.000.

Multiple Comparisons
Dependent Variable:
Tukey HSD

(I) GROUP		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
XC	TRACK	-6.000	3.480	0.202	-14.30	2.30
	TREADMILL	-10.033	3.480	0.014	-18.33	-1.73
TRACK	XC	6.000	3.480	0.202	-2.30	14.30
	TREADMILL	-4.033	3.480	0.481	-12.33	4.27
TREADMILL	XC	10.033	3.480	0.014	1.73	18.33
	TRACK	4.033	3.480	0.481	-4.27	12.33

*. The mean difference is significant at the 0.05 level.

POWER

Effect of Type of Running
(XC Vs Track Vs Treadmill on Mean Power for Runners)

Type of Running	X-COUNTRY	TRACK	TREADMILL
Type of Running	247.30	265.30	224.93
S.Error	9.57	8.26	11.00

Descriptives
POWER

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	Upper Bound	Minimum	Maximum
XC	30	247.30	52.438	9.574	227.72	266.88	184	349
TRACK	30	265.30	45.260	8.263	248.40	282.20	161	350
TREADMILL	30	224.93	60.251	11.000	202.44	247.43	101	325
Total	90	245.84	54.973	5.795	234.33	257.36	101	350

ANOVA
POWER

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	24537.356	2	12268.678	4.367	0.016
Within Groups	244420.467	87	2809.431		
Total	268957.822	89			

Tukey HSD[a]
POWER

GROUPS	N	Subset for alpha = 0.05 1	2
TREADMILL	30	224.93	
XC	30	247.30	247.30
TRACK	30		265.30
Sig.		0.237	0.391

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 30.000.

Multiple Comparisons
Dependent Variable:
Tukey HSD

(I) GROUPS		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
XC	TRACK	-18.000	13.686	0.391	-50.63	14.63
	TREADMILL	22.367	13.686	0.237	-10.27	55.00
TRACK	XC	18.000	13.686	0.391	-14.63	50.63
	TREADMILL	40.367	13.686	0.011	7.73	73.00
TREADMILL	XC	-22.367	13.686	0.237	-55.00	10.27
	TRACK	-40.367	13.686	0.011	-73.00	-7.73

*. The mean difference is significant at the 0.05 level.

Results:

CADENCE

Effect of Type of Running
(XC Vs Track Vs Treadmill on Mean Cadence for Runners)

Type of Running	X-COUNTRY	TRACK	TREADMILL
Type of Running	177.10	177.27	171.63
S.Error	1.55	1.65	1.67

Descriptives
CADENCEXC

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	Upper Bound	Minimum	Maximum
XC	30	177.10	8.462	1.545	173.94	180.26	163	198
TRACK	30	177.27	9.032	1.649	173.89	180.64	161	198
TREADMILL	30	171.63	9.148	1.670	168.22	175.05	158	194
Total	90	175.33	9.171	0.967	173.41	177.25	158	198

ANOVA
CADENCEXC

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	616.467	2	308.233	3.904	0.024
Within Groups	6869.533	87	78.960		
Total	7486.000	89			

Tukey HSD[a]
CADENCEXC

GROUPS	N	Subset for alpha = 0.05 1	2
TREADMILL	30	171.63	
XC	30		177.10
TRACK	30		177.27
Sig.		0.050	0.997

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 30.000.

Multiple Comparisons
Dependent Variable:
Tukey HSD

(I) GROUPS		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
XC	TRACK	-0.167	2.294	0.997	-5.64	5.30
	TREADMILL	5.467	2.294	0.050	0.00	10.94
TRACK	XC	0.167	2.294	0.997	-5.30	5.64
	TREADMILL	5.633	2.294	0.042	0.16	11.10
TREADMILL	XC	-5.467	2.294	0.050	-10.94	0.00
	TRACK	-5.633	2.294	0.042	-11.10	-0.16

*. The mean difference is significant at the 0.05 level.

STRIDE LENGTH

Effect of Type of Running
(XC Vs Track Vs Treadmill on Mean Stride Length for Runners)

Type of Running	X-COUNTRY	TRACK	TREADMILL
Type of Running	1.24	1.34	1.21
S.Error	0.038	0.046	0.046

Descriptives
STRIDELENGTHXC

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	Upper Bound	Minimum	Maximum
XC	30	1.2443	0.20597	0.03761	1.1674	1.3212	0.90	1.60
TRACK	30	1.3353	0.25242	0.04609	1.2411	1.4296	0.95	1.80
TREADMILL	30	1.1893	0.25623	0.04678	1.0937	1.2850	0.83	1.72
Total	90	1.2563	0.24422	0.02574	1.2052	1.3075	0.83	1.80

ANOVA
STRIDELENGTHXC

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.326	2	0.163	2.848	0.063
Within Groups	4.982	87	0.057		
Total	5.308	89			

Tukey HSD[a]
STRIDELENGTHXC

GROUPS	N	Subset for alpha = 0.05 1
TREADMILL	30	1.1893
XC	30	1.2443
TRACK	30	1.3353
Sig.		0.053

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 30.000.

Multiple Comparisons
Dependent Variable:
Tukey HSD

(I) GROUPS		Mean Difference (I-J)	Std. Error	Sig	95% Confidence Interval Lower Bound	Upper Bound
XC	TRACK	-0.09100	0.06179	0.309	-0.2383	0.0563
	TREADMILL	0.05500	0.06179	0.648	-0.0923	0.2023
TRACK	XC	0.09100	0.06179	0.309	-0.0563	0.2383
	TREADMILL	0.14600	0.06179	0.053	-0.0013	0.2933
TREADMILL	XC	-0.05500	0.06179	0.648	-0.2023	0.0923
	TRACK	-0.14600	0.06179	0.053	-0.2933	0.0013

*. The mean difference is significant at the 0.05 level.

Interpretation of Results and Conclusions:

HEART RATE

Aim: We are testing to see if there is a difference between the three types of running.
Hypothesis: Any difference in mean Heart Rate between the three groups (XC vs Track vs Treadmill) is due to a statistically significant difference between the three types of running.
Null Hypothesis: Any difference in Heart Rate between the three groups is due to a chance effect.
ANOVA Result: From the ANOVA results for Heart Rate comparison, the "F value" is 4.208 and the "p (Sig) value" is 0.018 (which is less than 0.05). This means that with a confidence of greater than 95% we can REJECT the Null Hypothesis and ACCEPT the Hypothesis above.
Interpretation: There is a statistically significant difference in Heart Rate between the three types of running groups as shown by one-way ANOVA (F(2,87) = 4.208, p = 0.018). In order to find out which groups are statistically significant different from each other we must carry out a Tukey honestly significant difference (HSD) "post hoc." test.
Tukey result and Conclusion: The Tukey (HSD) post hoc test showed that the mean Heart Rate running on the Treadmill was statistically significantly higher (168.87 B.P.M) than the mean Heart Rate during XC running (158.83). P(Sig) value = 0.014. There was no statistically significant difference between the mean Heart rates comparing XC and Track (p = 0.202) and Track and Treadmill (p = 0.481).

POWER

Aim: We are testing to see if there is a difference between the three types of running.
Hypothesis: Any difference in mean Power between the three groups (XC vs Track vs Treadmill) is due to a statistically significant difference between the three types of running.
Null Hypothesis: Any difference in Power between the three groups is due to a chance effect.
ANOVA result: From the ANOVA results for Power comparison, the "F value" is 4.367 and the "p (Sig) value" is 0.016 (which is less than 0.05). This means that with a confidence of greater than 95% we can REJECT the Null Hypothesis and ACCEPT the Hypothesis above.
Interpretation: There is a statistically significant difference in Power between the three types of running groups as shown by one-way ANOVA (F(2,87) = 4.367, p = 0.016). In order to find out which groups are statistically significant different from each other we must carry out a Tukey honestly significant difference (HSD) "post hoc." test.
Tukey result and Conclusion: The Tukey (HSD) post hoc test showed that the mean Power running on the Track was statistically significantly higher (265.30 Watts) than the mean Power during Treadmill running (224.93 Watts). P(Sig) value = 0.011. There was no statistically significant difference between the mean Power comparing XC and Track (p = 0.391) and XC and Treadmill (p = 0.237).

CADENCE

Aim: We are testing to see if there is a difference between the three types of running.
Hypothesis: Any difference in mean Cadence between the three groups (XC vs Track vs Treadmill) is due to a statistically significant difference between the three types of running.
Null Hypothesis: Any difference in Cadence between the three groups is due to a chance effect.
ANOVA result: From the ANOVA results for Cadence comparison, the "F value" is 3.904 and the "p (Sig) value" is 0.024 (which is less than 0.05). This means that with a confidence of greater than 95% we can REJECT the Null Hypothesis and ACCEPT the Hypothesis above.
Interpretation: There is a statistically significant difference in Cadence between the three types of running groups as shown by one-way ANOVA (F(2,87) = 3.904, p = 0.024). In order to find out which groups are statistically significant different from each other we must carry out a Tukey honestly significant difference (HSD) "post hoc." test.
Tukey result and Conclusion: The Tukey (HSD) post hoc test showed that the mean Cadence running on the Track was statistically significantly higher (177.27 strides per minute, SPM) than the mean Cadence during Treadmill running (171.63 SPM). P(Sig) value = 0.042. There was no statistically significant difference between the mean Cadence comparing XC and Treadmill (p = 0.050) and XC and Track (p = 0.997).

STRIDE LENGTH

Aim: We are testing to see if there is a difference between the three types of running.
Hypothesis: Any difference in mean Stride length between the three groups (XC vs Track vs Treadmill) is due to a statistically significant difference between the three types of running.
Null Hypothesis: Any difference in Stride length between the three groups is due to a chance effect.
ANOVA result: From the ANOVA results for Cadence comparison, the "F value" is 2.848 and the "p (Sig) value" is 0.063 (which is greater than 0.05). This means that as our confidence is less than 95% we must ACCEPT the Null Hypothesis and REJECT the Hypothesis above.
Interpretation: This means that the difference in mean stride lengths between the three types of running is DUE TO A CHANCE EFFECT and that there is NO statistically significant difference between them, although initially looking at the bar chart it might appear so.
Tukey result and Conclusion: The Tukey (HSD) post hoc test reinforces the above interpretation. When analysing the p (sig) values between the groups (running types), all of them have p values that are above p = 0.05. There was no statistically significant difference between the mean Stride length (in metres) when comparing XC and Track (p = 0.309) and XC and Treadmill (p = 0.648) and Track and Treadmill (p = 0.053)

Overall Conclusions/Recommendations

As shown in our results there is a complex relationship between the metrics measured. The XC metrics fell between Track and Treadmill, with the exception of Heart Rate. This is not what we originally hypothesised would happen, and warrants further investigation!
Afterall.........The more power a runner can generate at a lower heart rate (or faster pace) – the more efficient you are (at running)!
Efficiency is the secret weapon of fast runners, and in XC, Pace and Heart Rate are obviously affected by hills!

References:

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(2) Meyer J., Hein A. Live long and prosper: Potentials of low-cost consumer devices for the prevention of cardiovascular diseases. J. Med. Internet Res. 2013;15:1–9. doi: 10.2196/med20.2667. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
(3) The Science of Running-Steve Magness
(4) The History of Running-A Brief Introduction-Rockay
(5) "History of Running". Health and Fitness History. 23 November 2018. Retrieved 23 November 2018.
(6) Designing conference posters - Colin Purrington. 2015. Designing conference posters - Colin Purrington. [ONLINE] Available at:http://colinpurrington.com/tips/academic/posterdesign#templates. [Accessed 02 January 2015]